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A COMPUTATIONAL STUDY OF AN INTAKE MANIFOLD FOR FOUR STROKE S.I. ENGINE

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ABSTRACT

In the recent era, energy is more preferred to be produced from renewable energy resources rather than from non-renewable resources. Both non-renewable and renewable energy resources have their own limitations such as the set up cost for renewable is high whereas pollution from non-renewable is high. Based on the limitations, researchers focused on the emission control in automobiles rather than using non-renewable sources. This forms the major objective for the engine designers to achieve lowest possible emission level with efficient combustion. Studies on emission level reduction shows that the flow harnessing in the intake manifold of IC engine can yield improvement in engine torque up to 10% along with a nominal decrease in emission level. The researches reveal that the optimization of an intake manifold plays an important role in manifold design to maximize the mass of air inducted into the cylinder for efficient combustion. Traditional manufacturing of intake manifolds and the trial and error method to select an optimized manifold is time-consuming and cost-effective. This work focuses on the design of an intake manifold with the different configuration such as normal, convergent and venture types and the study of the airflow through each designed manifolds has been performed using CFD. On comparison of the analysis results, an optimized intake manifold which allows maximum air flow inside the cylinder has been selected for efficient combustion.

KEYWORDS: Intake Manifold, Venturi, Air-Fuel Ratio & Velocity Contour

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Original Article

INTRODUCTION

Nowadays, the focus of the engine designers has been shifted to the best performance and lowest possible emission level of Internal Combustion (IC) engines. In an IC engine, efficient combustion along with stoichiometric air-fuel ratio is the input for an excellent engine performance. The flow characteristics of air and fuel within the combustion chamber plays a vital role for a good combustion. In a naturally aspirated engine, the torque can be increased to an optimized level (nearly 10%) through the harness of fuel and air flow into the intake manifold. The design of an intake manifold should be optimized as it plays an important role in maximizing the mass of air inducted into the cylinder. In case of multi-cylinder engine, optimization of the intake manifold is difficult as there should be equal flow distribution in all cylinders. This indicates the importance of intake

manifold geometry for engine design for its best performance.

Manufacture of different intake manifold prototypes for a traditional optimization may not be cost-effective as the process is expensive. Testing of these prototypes in an IC engine may be time-consuming. The experimentation results of these prototypes may not show the flow characteristics of the air-fuel mixture. A correct prediction in the selection of an appropriate manifold design can't be done by the engine designers without the flow observation. Computational analysis of the flow by CFD software is one of the possible ways to obtain an optimized design with a reasonable amount of time and cost.

A fuel-air mixture (S.I. engine) (or) only fresh air (C.I. engine) is supplied through the intake (or) inlet manifold to the engine for combustion. Distribution of combustible mixture to each intake port in the cylinder head is the prime base function of an intake manifold. Aluminum (or) Cast iron was the two materials which have been used for the manufacture of the intake manifold. Nowadays, composite materials were used for better thermal conductivity.

Sujith G et al [1] has studied about the modification and analysis of 125 cc Petrol Engine with a turbocharger. By installing a garret turbocharger, the power and overall performance of an engine can be dramatically increased. Manoj Prajapati et al [2] investigated the effect of swirl on the performance characteristics of the engine as well as on its exhaust emissions.

Shrinath potul et al [3] analyzed the performance characteristics of an IC engine and its variation with the change in length of the intake manifold. The experimental results have been compared with the results of a Lotus Engine Simulation, a virtual simulation software. The design of an intake manifold of Maruti Wagnor has been improved by Sachin Singla et al [4] and the variation of velocity and pressure at outlet has been studied at different inlet velocities. Investigation of the air flow behavior at different intake manifold angles for small 4-stroke PFI retrofit kit system has been done by Mohd Faisal Hashim et al [5] in order to select an optimized angle for better air flow behavior.

The influence of different intake manifolds on the atomization and distribution of fuel injected in the combustion chamber for better CI engine performance has been studied by Yogesh R.Rithe et al [6]. The effect on the volumetric efficiency of an IC engine has been studied with varying length of intake manifold by Bayas Jagadish G.et al [7]. The torque and brake power was also observed at different lengths.

Ch.Indira priyadarshini et al [8] analyzed the structure of an intake manifold against the bursting pressure using CFD. The plenum chamber in an intake manifold of a multicylinder SI engine has been investigated for its volumetric efficiency by C. Ramesh Kannan et al [9] through computational analysis.

PROBLEM DEFINITION

The project started with the main motive to increase the engine efficiency. For that several method were sorted out which includes the preheating the air-fuel mixture by recovering the exhaust gas heat. Since the method was quite dangerous to do it was dropped out. From the above literatures a conclusion has been derived with the modification of the intake manifold shape which leads to increase in efficiency with minimum pressure drop.

EXISTING MODEL

PTC CREO Package was used to design the geometry for the intake manifold of different shapes such as normal and venture. The designed geometries were shown in Figure 1 and Figure 2 Figure 1 shows the design of a normal intake manifold which is used in IC engines at current scenario.

Figure 1: Intake Manifold- Normal

MODIFIED MODEL

Principle of the Model

Fuel droplets are sprayed through fuel injectors into the air (from the intake manifold). In order to increase the effect of atomization, creation of turbulence (increase in velocity) during the intake or suction of air is an effective method which in turn burns all the fuel completely and helps incomplete combustion. Therefore, the intake manifold can be modified in such an geometry to increase the air velocity at the outlet of the manifold.

The velocity of a fluid can be increased by passing it through a constriction. When it passes through the constriction, its kinetic energy is increased and in turn, its velocity also increases which is depicted in Figure 2.

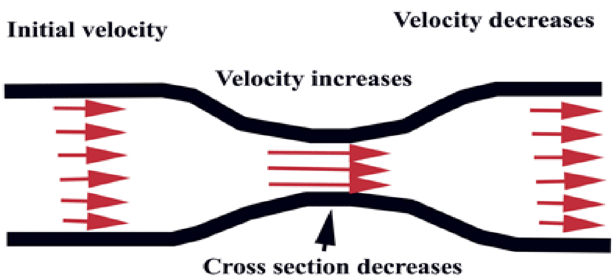


Figure 2: Principle of Venturi Effect

Venturi effect is used in carburetors to suck the fuel into engine's intake system. But the installation of the venturi in intake manifold will allow an increase in the velocity with minimum pressure drop. The swirling movement in the intake manifold due to venturi will help maximum mixing of air with the fuel.

The venture effect has been implemented in the normal intake manifold to modify as venturi intake manifold whose model is shown in Figure 3. Venturi geometry consists of three sections: Convergent, Straight and Divergent. Each section has different functions where the velocity of air increases in the straight portion of the manifold (called as throat) that helps in increase in velocity and in the diverging section, recovers the pressure drop. The geometry varies with variation in diameter at each section of the manifold which is shown in Table 1.

Table 1: Manifold Diameter - Section Wise

Manifold Section	Diameter
Convergent	25 mm
Throat (Straight)	22.5 mm
Divergent	23 mm

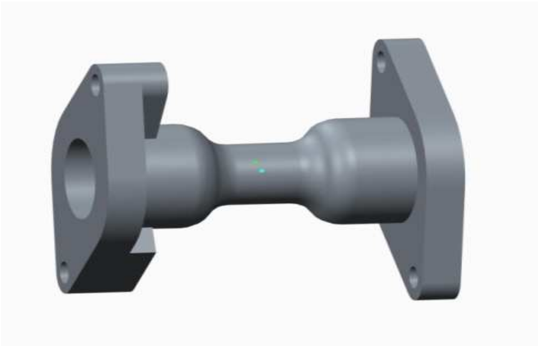


Figure 3: Modified Intake Manifold- Venturi Type

COMPUTATIONAL ANALYSIS

The equations which are shown in Table 2 are the basic governing equations for determining the flow characteristics through computational fluid dynamics.

Table 2: CFD Governing Equations

Basic Governing CFD equations	Continuity Equation	$\frac{\partial \rho}{\partial t} + \nabla.(\rho.\vec{V}) = 0$
	Momentum Equation	$\frac{\partial(\rho.u)}{\partial t} + \nabla.(\rho u\vec{V}) = \frac{-\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \rho f_x$
	Energy Equation	$\rho \frac{d}{dt}\left(e + \frac{V^2}{2}\right) = \rho q - \frac{\partial(up)}{\partial x} - \frac{\partial(vp)}{\partial y} - \frac{\partial(wp)}{\partial z} + \rho\vec{f}\vec{V}$

Parameters Required for the Computational Analysis

For the CFD analysis of the inlet manifold to be done parameters that are too calculated are

- A Velocity of air-fuel mixture in the inlet manifold
- A Temperature of the air-fuel mixture in the inlet manifold
- The Pressure inside the inlet manifold

THEORETICAL CALCULATION

The theoretical values for velocity an pd flow rate can be obtained by the equations (1) & (2) with known parameters such as pressure inside the inlet manifold, density of air and cross -sectional area of the manifold.

Velocity of air at inlet, $V = \sqrt{\frac{P}{\rho}}$ (1)

Mass flow rate of the air at inlet, $\dot{m} = \rho \times V \times A$ (2)

Where,

V = Velocity across the intake manifold (m/s)

P = Pressure inside the intake manifold (N/m^2)

ρ = Density of air fuel mixture (kg/m^3)

A= Cross sectional area of the intake manifold (m^2)

EXPERIMENTAL EVALUATION

For the convenient measurement of mass flow rate of the air, a sensor was installed on the pathway of inlet manifold along with a temperature indicator for temperature measurement. The flow sensor (Figure 4 (a)) has been fixed to the inlet manifold of an experimental test rig (Figure 4 (b)) which consists of a BAJAJ CT 100 engine coupled with a rope brake dynamometer.

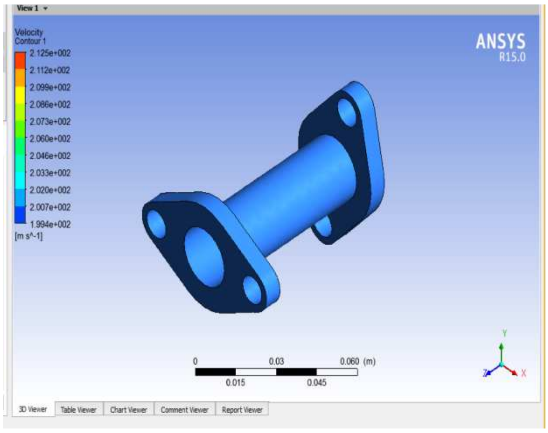
Figure 4 (a): Flow Sensor

Figure 4 (b): Experimental Test Rig

RESULTS & DISCUSSIONS

The flow rate of air at the inlet of the manifold was measured with the help of flow sensor at different loads. The inlet velocity of the air is calculated by (1) and (2) through the inputs such as pressure, mass flow rate, a density of the air and the area of the intake manifold. The results calculated from (1) and (2) were made as inputs for the computational analysis.

The velocity variation of air through the normal intake manifold is depicted in Figure 5 (a) with maximum velocity at the exit of the manifold. In Figure 5 (b), the streamlines indicates that the exit velocity is greater than the inlet velocity of air through the manifold.



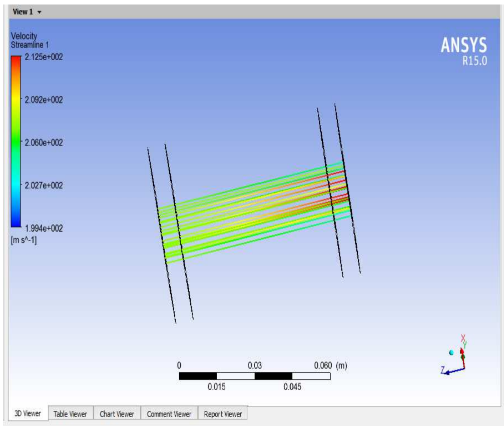
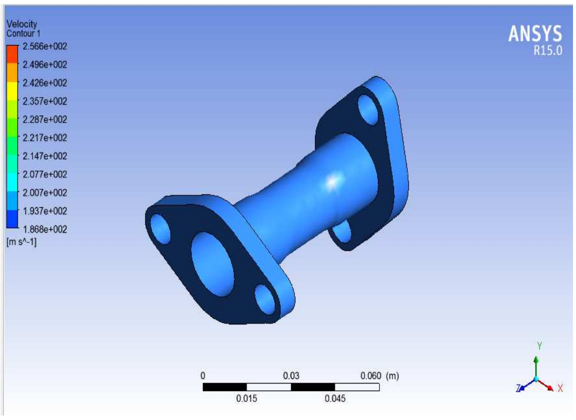


Figure 5 (a): Flow Analysis **Figure 5 (b): Stream Line**

The results obtained from the computational analysis using ANSYS was shown in Table 3. It shows that the exit velocity is greater than the inlet velocity at different load conditions.

Table 3: Computational Results –Normal Type

S.No	Load	Flow Rate	Inlet Velocity	Pressure	Temperature	Exit Velocity
	kg	l/hour	m/s	bar	°C	m/s
1	0	320	207	0.52	31	212
2	2	458	300	1.1	32	307.303
3	4	544	356	1.5	34.7	364.441



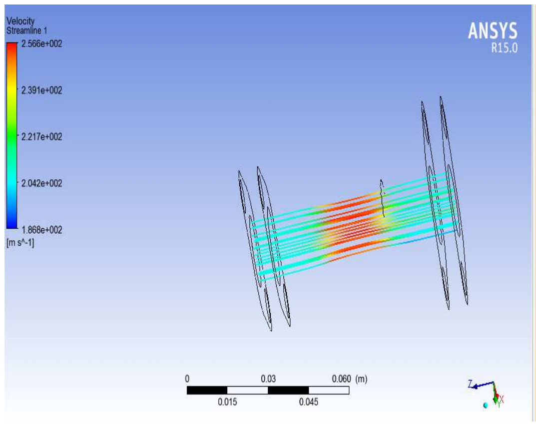


Figure 6 (a): Flow Analysis **Figure 6 (b): Stream Line**

The velocity variation of air through the venturi intake manifold is depicted in Figure 6 (a) with maximum velocity at the throat of the manifold. In Figure 6 (b), the streamlines indicate that the throat velocity is greater than the inlet and exit velocity of air through the manifold.

Table 4: Computational Results –Venturi Type

S.No	Load	Flow Rate	Inlet Velocity	Pressure	Temperature	Throat Velocity
	kg	l/hour	m/s	bar	°C	m/s
1	0	320	207	0.52	31	256.494
2	2	458	300	1.1	32	371.512
3	4	544	356	1.5	34.7	440.751

The results obtained from the computational analysis using ANSYS was shown in Table 4. It shows that the air velocity at the throat is greater than the inlet velocity at different load conditions.

CONVERGENT INTAKE MANIFOLD

- The convergent nozzle is a spout that begins large and gets smaller, an abatement in the cross-sectional region.
- As a liquid enters the smaller cross-area, it needs to accelerate because of the production of mass. To keep up a consistent measure of liquid traveling through the confined bit of the spout, the liquid must move faster.

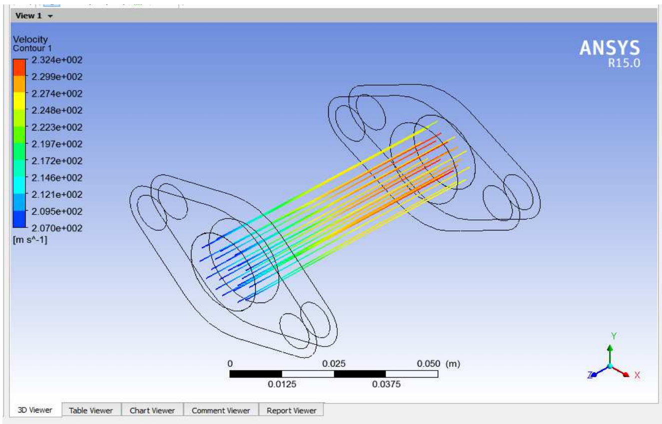


Figure 7

The results obtained from the computational analysis using ANSYS was shown in Table 4. It shows that the air velocity at the throat is greater than the inlet velocity at different load conditions. The velocity variation of air through the convergent intake manifold is depicted in Figure 6 (a) with maximum velocity at the exit of the manifold

Table 5

S.No	Load	Flow Rate	Inlet Velocity	Pressure	Temperature	Throat Velocity
	kg	l/hour	m/s	bar	°C	m/s
1	0	320	207	0.52	31	233.83
2	2	458	300	1.1	32	336.441
3	4	544	356	1.5	34.7	399.01

Table 6: Comparison of Results

Load (kg)	Inlet Velocity (m/s)	Exit/Throat Velocity (m/s)	
		Normal	Venturi
0	207	212	256.494
2	300	307.303	371.512
4	356	364.441	440.751

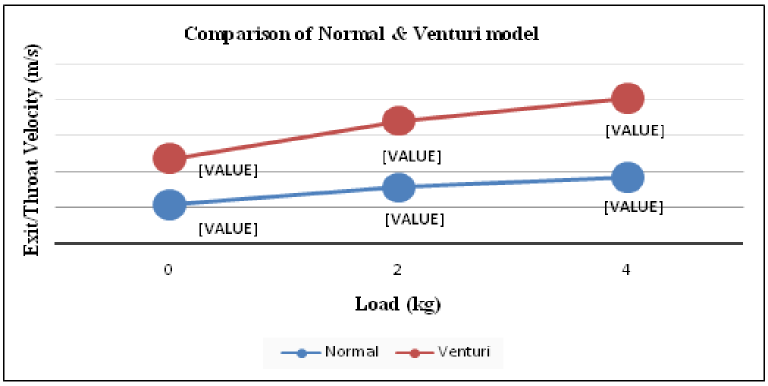


Figure 8: Comparison Graph

The computational results for the normal and venturi-type manifold have been compared and shown in Table 6 and depicted in Figure 8 in the form of the graph. The results indicate that the flow of air through the venturi intake manifold is higher than the normal intake manifold.

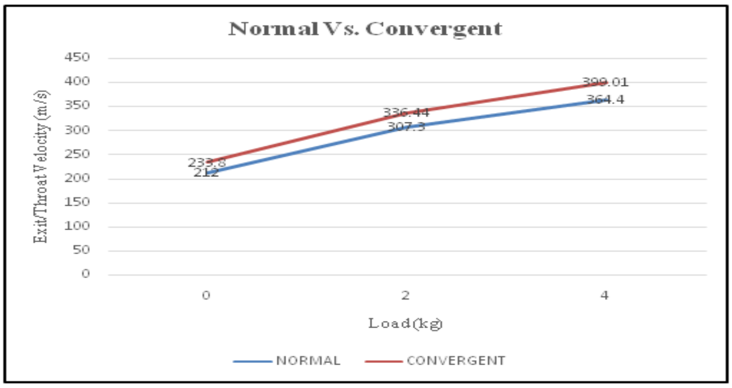


Figure 9

Table 7

Load (kg)	Inlet Velocity (m/s)	Exit/Throat Velocity (m/s)	
		Normal	Convergent
0	207	212	233.83
2	300	307.303	336.441
4	356	364.441	399.01

CONCLUSIONS

The flow evaluation of air through the intake manifold with different configurations was focused in this work. Existing manifold with normal configuration and the modified manifold with venture configuration was designed using PTC Creo tool The designed manifolds were analyzed using ANSYS fluent to evaluate the flow characteristics of air through intake manifolds. The computational results indicate that the air velocity is 25% higher in the venturi manifold than the normal one at maximum load condition. The mass flow rate of air entering the carburetor was also increased with increase in velocity which in turn provides efficient combustion.

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